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WATER RESOURCES IN THE HIGH PLAINS OF TEXAS AND NEW MEXICO

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CONTENTS

	Page
Introduction	3
Surface water resources	3
Precipitation	5
Playas	5
Runoff	5
Streamflow	6
Ground-water resources	6
Ogallala formation	6
Use of ground water	8
Summary	12
References	12

WATER RESOURCES IN THE HIGH PLAINS OF TEXAS AND NEW MEXICO[1]

Wayne Clyma and F. B. Lotspeich[2]

INTRODUCTION

Growing concern about water resources of the Southern High Plains prompted a recent strengthening of the water conservation research program at the Southwestern Great Plains Research Center at Bushland, Tex. A literature review, completed as a part of this new emphasis on water research, revealed that information on the problem is scattered in many reports and that no single report covered the entire area. The objective of this report is to collect all the pertinent information into one short publication that describes the water resources of the area, points out the serious problem of exploiting this resource, and offers some suggestions that will prolong the life of the aquifer through research or improved efficiency of water use.

Total area of the High Plains of Texas and New Mexico (figure 1) is approximately 25 million acres. Knowledge of water resources in this area is vital because most water available for man's use comes from a rapidly diminishing ground-water supply. The economy of the area depends substantially upon an irrigated agriculture and more than 5 million acres are irrigated annually from ground-water supplies in the Texas High Plains alone (29)[3].

Ground water in the High Plains area is essentially being mined because withdrawals exceed natural recharge. That portion south of the Canadian River was listed in the 1955 Yearbook of Agriculture, Water, as the largest irrigated area in the United States with an overdraft of ground-water supplies (31, p. 70).

SURFACE WATER RESOURCES

Geologic conditions control surface-water and ground-water supplies of the High Plains. The area is in a very youthful stage of the geomorphic cycle and is virtually untouched by erosion except on its margins. The surface slopes to the southeast at 8 to 10 feet per mile, but the local topography is interrupted by numerous enclosed basins containing playas. Otherwise, only a few shallow draws occur in the area and one perennial stream, the Canadian River, crosses the plateau and drains that portion contained in its valley. Water flows in the draws only during periods of unusually heavy or sustained rainfall and is accumulated from small areas adjacent to the draws. All the rainfall runoff from most of the area is collected by thousands of enclosed basins that dot the High Plains to form playas and is retained in the area.

The aquifer is isolated from the Rocky Mountains to the west by the Pecos and Canadian Valleys. Therefore, natural recharge by water from the Rocky Mountains is impossible.

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[1] Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Texas Agricultural Experiment Station, Texas A.& M. University.

[2] Formerly research agricultural engineer, USDA, Bushland, Tex., presently agricultural engineer, Oklahoma State University, stationed at Imperial Ethopian College, Dire Dawa, Ethiopia; and research soil scientist, USDA, Bushland, Tex.

[3] Underscored numbers in parentheses refer to references at end of report.

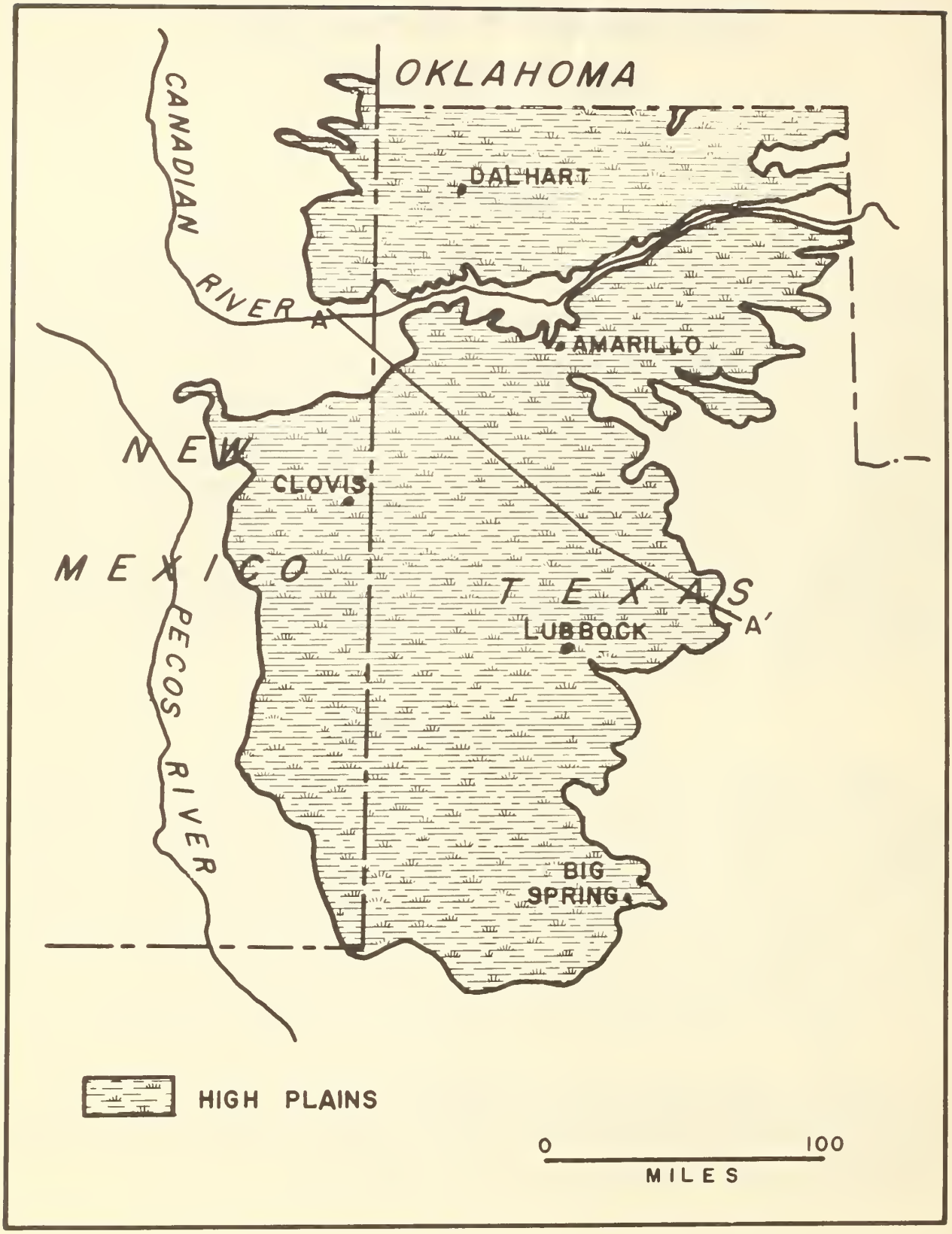

Figure 1.--Location map of the High Plains of Texas and New Mexico. A _ A' cross section shown in figure 2.

Precipitation

Precipitation furnishes the largest volume of water available to the area. Moisture for rainfall on the High Plains is predominantly tropical maritime and is supplied principally from the Gulf of Mexico. The average annual precipitation ranges from 12 inches in the west to 24 inches in the east and tends to have a summer peak. For example, at Amarillo, Tex., 51 percent of the average annual precipitation occurs during June through September (15). Average rainfall figures are misleading, however, because of wide variations in rainfall from year to year and distribution within a year. As an example, weather records for Bushland, 14 miles west of Amarillo, show a total of 32.6 inches rainfall in 1941 with 9.1 inches received in October; in 1960, out of a total of 31.4 inches, 15.2 inches fell during June and July. The driest year on record at Bushland was 1940 when 12.1 inches of rain was caught with May receiving 4.2 and November 3.4 inches; thus, 63 percent of the total yearly rainfall was caught during these two widely separated months.

Playas

Playas range in size from a few acres to several square miles and in depth from 2 feet to as much as 50 feet. Most playas are circular to oval and watershed configurations tend to be similar. Most are single basins, although some have an integrated watershed that combines several adjacent basins, usually arranged in a line. The origin of these basins is unknown, although several hypotheses have been offered (12, 18).

Although not striking from a geomorphological standpoint, thousands of playas dot this otherwise featureless plain. Water that accumulates in the playas furnishes the principal water source to recharge ground-water supplies or furnish supplemental irrigation water. However, only a small volume of surface water reaches the aquifer under natural conditions because of the low permeability of the playa sediments and the high evaporation rates of the region.

Runoff

Estimates based on information from the Soil Conservation Service Engineering and Watershed Planning Unit in Fort Worth, Tex., and rainfall-runoff relationships from the SCS Hydrology Guide (4) indicate that runoff for the area averages 0.84 inch annually. Zingg and Hauser (34) have estimated the runoff for dryland conditions to be about 1 inch per year. (Runoff from irrigated areas should be higher.) Data from the Texas Water Commission (formerly Texas Board of Water Engineers) (10) showed an annual runoff of 0.5 and 2.5 inches for 2 years for an area near Plainview, Tex. In 1957 annual rainfall for three stations near the study area averaged 17 percent above normal and in 1958 averaged 13 percent below normal. Additional Texas Water Commission data are presented in table 1.

Table 1.--Hydrologic data for an area near Plainview, Tex.[1]

Item	1957	1958
Lakes in study area ..... number..	1,348	1,348
Total catch ..... acre-feet..	199,096	37,025
Annual rainfall ..... inches..	27.0	18.5
Average annual runoff from drainage area..... inches..	2.5	0.47

[1] Data were collected for only the 2 years shown (10).

Using the above-cited runoff figures, computations show that annual runoff into playas ranges between 1.8 and 5.7 million acre-feet for the entire area. Most of this water evaporates.

Streamflow

Streams collect an estimated 0.5 million acre-feet of runoff from the area. This is about 13 percent of the average runoff collected by playas, although these streams only drain 5 to 10 percent of the area. Annual surface runoff volume contributed to streams that traverse the area is shown in table 2. This is not the total volume of runoff from the High Plains (all streams are not gaged), but it does include some drainage from below the escarpment (especially the station near Estelline). Much of the runoff that reaches the ephemeral streams of the High Plains never arrives at the gaging stations because of absorption into dry, sandy streambeds. White et al. (32) stated that in May 1937 the peak flow of Running Water Draw at Plainview was 1,200 cubic feet per second (c.f.s.) while about 15 miles below Plainview the peak flow was only 80 c.f.s. Long (21) also concluded that the draws are sources of recharge when they carry runoff because the water level rose in wells near draws after they flowed.

Table 2.—Average annual streamflow in the principal streams of the Panhandle of Texas (2)

Station	Drainage area	Primary contributing area	Average discharge
	Sq. miles	Sq. miles	Acre-ft./yr.
Logan, N. Mex.[1]	--	3,040	203,680
Canadian River near Canadian, Tex.	22,866	11,267	450,300
Palo Duro Creek near Spearman, Tex.	960	440	15,570
Wolf Creek at Lipscomb, Tex.	697	475	28,740
Prairie Dog Town Fork Red River near Estelline, Tex.	7,293	2,524	110,800
Salt Fork Red River near Wellington, Tex.	1,222	1,013	66,610
Quitaque Creek near Quitaque, Tex.	293	35	5,560
Double Mountain Fork Brazos River at Lubbock, Tex.	--	--	1,210
White River at Plainview, Tex.	--	--	3,550

[1] Bureau of Reclamation, Private Communication. This figure should be subtracted from the one near Canadian to arrive at the volume produced between the two stations.

GROUND-WATER RESOURCES

Ground water is second in importance to rainfall as a water resource in the High Plains. The ground-water supply available from storage for the High Plains of Texas and New Mexico was estimated to be approximately 500 million acre-feet before development began (5, 7, 10, 21, 33). Estimates (32) of ground-water loss through springs and by evapotranspiration indicate the average recharge to be in the order of 0.10 inch per year. Theis (30) has also estimated the annual recharge rate to be in the order of a fraction of an inch.

This discussion will be limited to the main aquifer in the area, the origin of its water, and the overlying (Pleistocene) mantle. For a fuller treatment of the geohydrology see Cronin (10), Alexander (5), and Long (21).

Ogallala Formation

Description

The aquifer that supplies most of the ground water for this region, known as the Ogallala formation, is one of the most extensive, continuous aquifers in this country. A geologic cross section of the High Plains shown in figure 2 illustrates the location of this formation. It consists primarily of sands which are a continental, sedimentary unit of Pliocene age. This formation

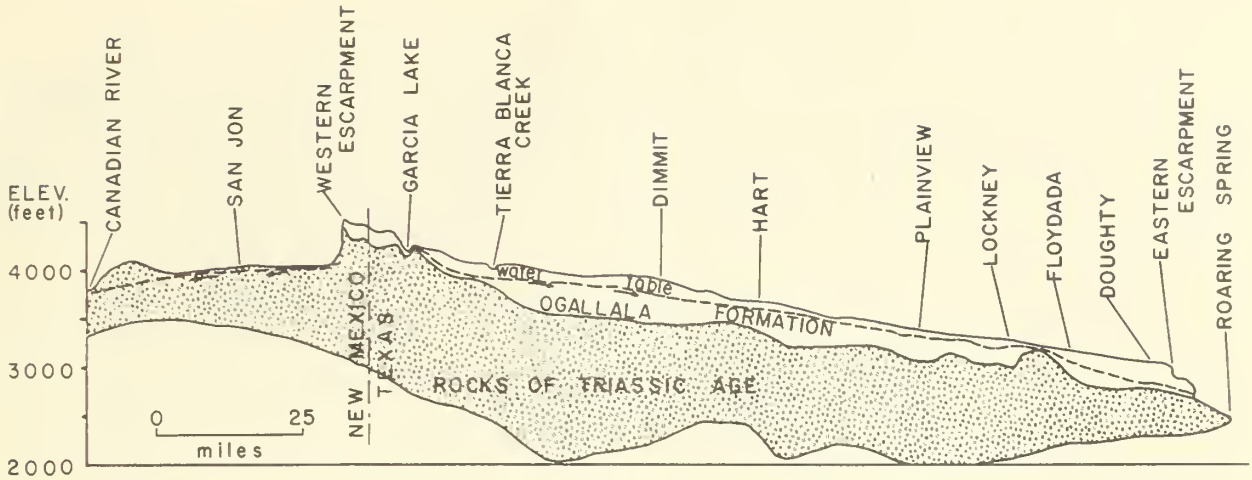

Figure 2.--Geologic cross section of the High Plains of Texas and New Mexico (12). Section drawn along A_ A' of figure 1.

originated as stream-transported debris, derived from rapid erosion of older sediments and crystalline rock during the Rocky Mountain uplift (18). As uplift continued, the eastward flowing streams carrying this material began aggrading as their gradients were reduced when they debouched onto the plains to the east. This aggradation resulted in broad, thin, coalescing fans with a wide range in texture from clay, silt, and sand to gravels. Formation thickness ranges from a few feet to as great as 900 feet with these variations following topographic surfaces of the earlier erosional cycle. Generally, these sands contain considerable clay in the upper part of the section and have many calcareous zones throughout the section.

The top of the Ogallala is marked by an indurated caliche layer and causes the escarpment which is a distinct feature of the region. The bottom usually rests on redbeds of Triassic age, although in Carson and Gray Counties it rests on the redbeds of Permian age. South of Plainview and in the extreme northwest, Cretaceous rocks underlie the Ogallala.

The hydraulic properties of the Ogallala appear to vary considerably from place to place. Data from published sources on the properties of the Ogallala are shown in table 3. Data for Amarillo and Plainview are probably the most reliable as they were from tests of several months' duration.

Table 3.--Properties of the Ogallala formation.

Location	Specific yield	Permeability	Transmissibility	Source
	Percent	G.p.d./ft.^{2}	G.p.d./ft.^{2}	
"Plainview District"[1]	14.1	--	--	(6)
"Hereford District"[1]	14.5	--	--	(6)
Ogallala[2]	15 to 20	--	--	(8)
Amarillo[3]	9 to 16(14)	--	6,000 to 7,000	(22)
Plainview[4]	11 to 14(14)	100 to 170	34,000 to 38,000	(11)
Lamb County[5] (sand hills)	--	--	63,000 to 153,000	(19)
Lea County[2] (New Mexico)	--	[6] 15 to 125	--	(30)

[1] Computed from estimates of the volume of water pumped and the average decline of the water table.
[2] Determined from laboratory analysis of samples.
[3] Long duration (111 to 113 days) recharge tests.
[4] Long duration (4 months) pumping test.
[5] Pumping tests of 24 and 39 hours.
[6] Average 60.

Origin of the Water in the Aquifer

Originally the sands and gravels of the Ogallala were saturated by the stream waters that deposited them. A long period of aridity followed deposition of these sands in the late Pliocene age, as evidenced by the strong caliche deposits characteristic of this region. Most of the water that saturated the sands at deposition was probably lost during the arid period when the caliche formed. During late or post Pleistocene, climates were considerably cooler and more moist than the present (20). It is possible that during this pluvial cycle enough rainfall occurred to saturate the aquifer.

At the time heavy pumping commenced, only about 50 percent of the aquifer was saturated under that part northeast of a line from Floydada in Floyd County to Adrian in Oldham County. This area contains silty clay soils and, under these conditions, time or the rate of recharge has been insufficient to fill the aquifer. Because of the slow rate of recharge, lateral movement to the southeast, which forms springs at the escarpment, prevented complete filling of the aquifer in some areas. Recharge continues at a slow rate under the present semiarid climate and, assuming there is no pumping, should refill the aquifer to the level that existed prior to pumping if given enough time.

USE OF GROUND WATER

Irrigation began near Portales, N. Mex., and near Plainview and Hereford, Tex., as early as 1910 (10, 11). North of the Canadian River, irrigation first began in the 1930's (5). This lag in irrigation development north of the river was closely related to the depth to ground water. The first wells were in the areas where the depth to ground water was less than 50 feet. More rapid development began in other areas of the High Plains in 1938, and development accelerated even further during a severe drought that started in 1952. In 1962, there were 52,500 wells irrigating over 5 million acres. Other factors that contributed to irrigation development were the introduction of more efficient pumping units and availability and use of natural gas as a power source.

The volume of water available from storage in the Ogallala as of 1958 in the High Plains of Texas was estimated to be about 400 million acre-feet (5, 10, 21) and the volume in New Mexico to be about 50 million acre-feet (7, 21, 33). These estimates were based on a specific yield of 15 percent.

Figure 3 shows the development of wells, and acres irrigated in the High Plains since 1948. The curves denote present trends--acres irrigated becomes static whereas total number of wells continues to increase. These trends probably result from a reduction in yield of wells as water tables decline and more wells are required to produce a given volume of irrigation water.

Ground-water supplies in 1958 are indicated in figure 4 by showing saturated thickness of the aquifer underlying the area. Approximately 10 percent of the original volume had been depleted by 1958 with the major depletion occurring since 1950. A map of the amount of water level decline that occurred between 1938 and 1958 is shown in figure 5. This decline is closely related to water table depth and well density. The decline of the water table shown in figure 5 should be evaluated only in light of the thickness of the saturated material shown in figure 4. In some areas where as much as 100 feet of decline had occurred, the aquifer initially contained 400 feet of saturated material. In other areas where only 50 feet of decline had occurred, there was initially only 100 feet of saturated thickness. Therefore, the latter has received twice as much storage depletion on a percentage basis. Hughes and Magee (14) stated that, as of 1958, in the area of the High Plains south of the Canadian River declining water levels seriously affected 20 percent of the area and moderately affected 64 percent of the area.

As ground-water levels decline, well yield also declines. Additional wells can be drilled to maintain present rates of ground-water withdrawal; however, economic considerations will limit

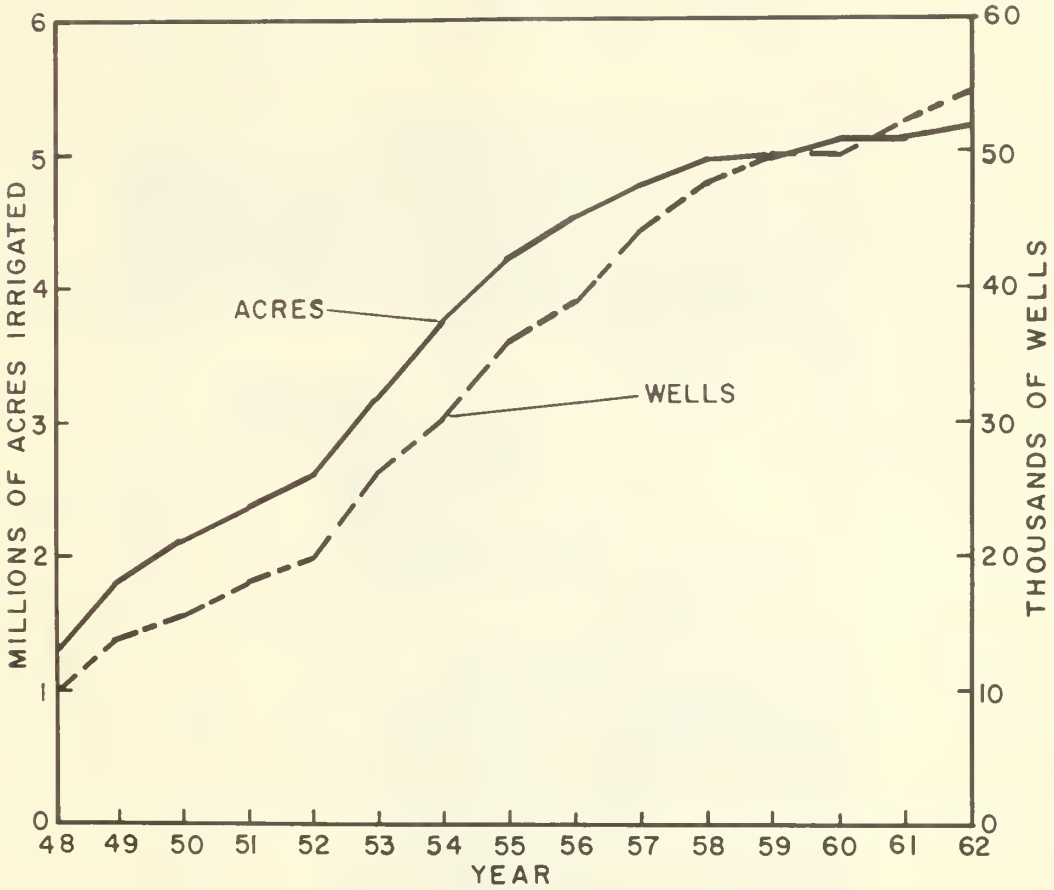

Figure 3.--Development of ground water (acres irrigated and wells) in the High Plains of Texas and New Mexico (21, 24-28).

this activity. Therefore, it is obvious that throughout the region, ground-water pumping cannot always exceed recharge and that where this occurs a new hydrologic equilibrium will be produced. Irrigation wells tapping the thicker parts of the irregular aquifer would continue to yield water, whereas those where the aquifer is thin would go dry. The new equilibrium condition would be reached when the withdrawal from these remaining wells would equal the rate of recharge to the aquifer. This new equilibrium level will be determined largely by economics but, whatever the level, the yield of water per well will be considerably lower than it is at present.

However, the rate of decline may be retarded as new knowledge from research becomes available to increase water-use efficiency and to accelerate the present slow rate of recharge.

Current practices of irrigating for highest yields usually do not obtain the most efficient water use (in terms of yield per unit volume of water applied). Data by Jensen and Sletten (16, 17) show that more pounds of grain sorghum and wheat per volume of water applied can be obtained by applying less irrigation water than that required for maximum yields. Bilbro et al. (9) have shown that limited irrigation produces more pounds of lint cotton per volume of water applied. Also, effective utilization of fertilizer results in more efficient use of irrigation water (16, 17).

It may be possible to increase usable water supply by: (1) constructing detention reservoirs on streams to increase ground-water recharge, (2) recharging the aquifer from playas, and (3) pumping directly from playas for irrigation.

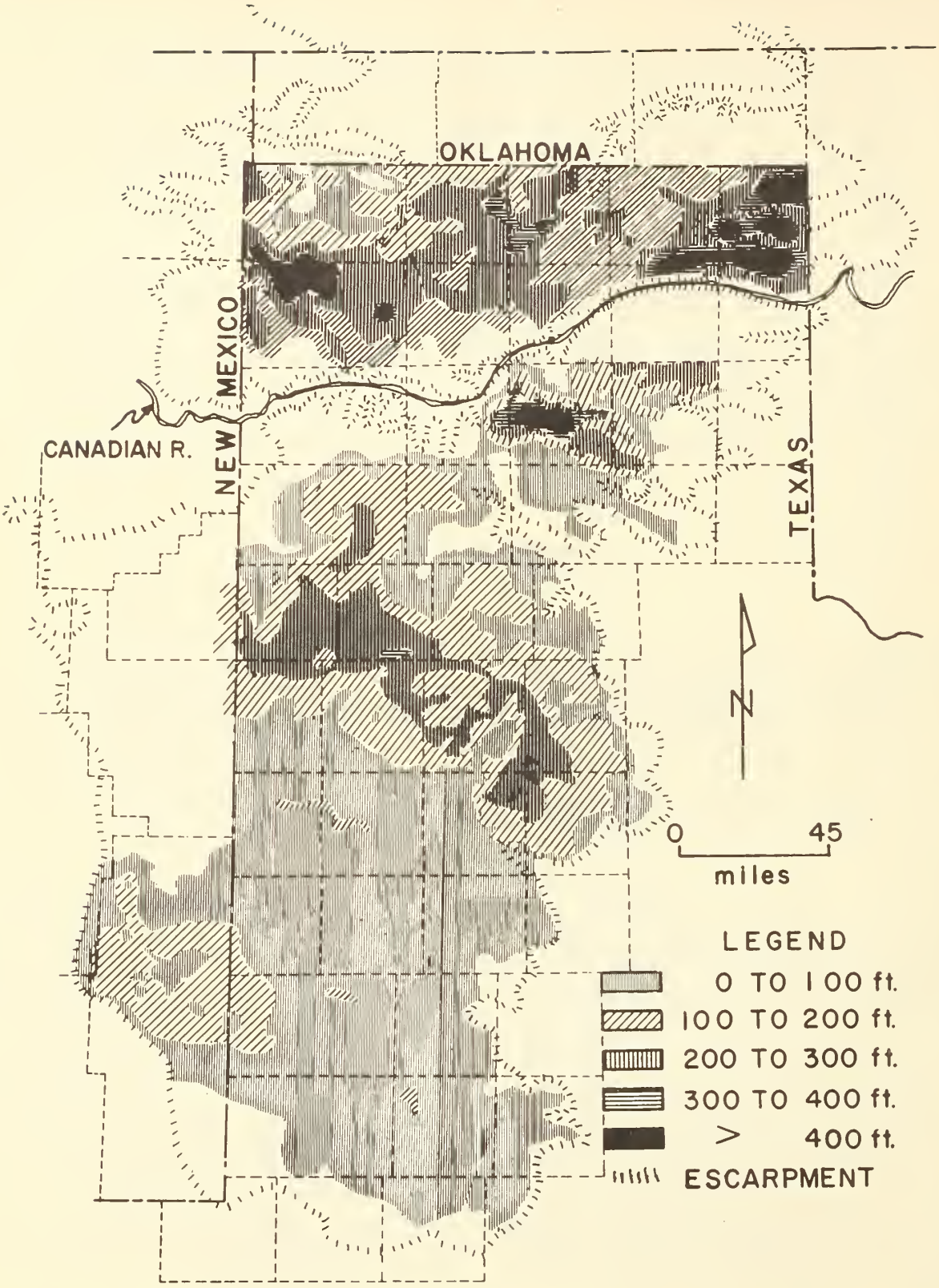

Figure 4.--Approximate thickness of the saturated material in the Ogallala formation, 1958, High Plains of Texas and New Mexico (7, 10, 12, 32).

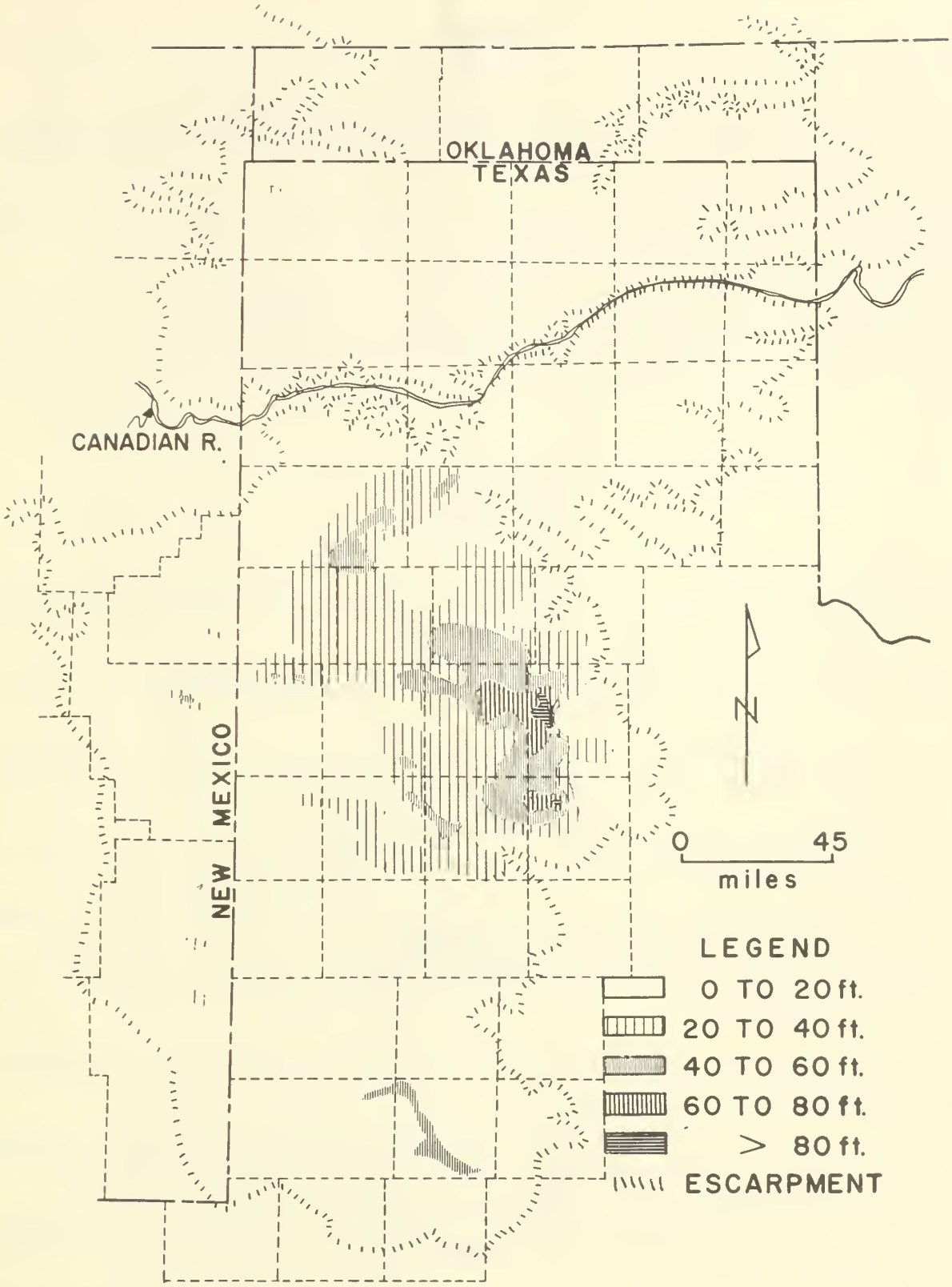

Figure 5.--Approximate decline of the water table elevation in the Ogallala formation 1938-1958, High Plains of Texas and New Mexico (1, 7, 10, 12, 23-27, 32).

SUMMARY

Geologic conditions have an unusual effect on the surface-water and ground-water supplies of the High Plains. The playa topography retains water in the area that would ordinarily be discharged to streams. Geologic processes have isolated the aquifer from possible sources of recharge in the Rocky Mountains.

Approximately 450 million acre-feet of water were available from storage in the High Plains of Texas and New Mexico as of 1958. But, these ground-water supplies are being depleted much faster than they are replenished through natural recharge.

Surface water resources of the area are estimated to average between 1.8 and 5.7 million acre-feet annually from runoff into playas and 0.5 million acre-feet from stream runoff. Much of this water is not being used to supplement ground water. Economic conditions or laws will eventually restrict removal of ground water and permit the establishment of a new hydrologic balance.

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